Analysing the Influence of Route Choice on Traffic Flow with Speed Profiles

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Abstract
The GPS trajectories of test vehicles are used to compare the influence of route choice on the travel time between a common origin and destination. The speed profiles are used to calculate the stop duration at traffic lights and the fuel consumption per vehicles. These performance indicators are compared between two groups of vehicles following the route advice of load balanced routing and individualistic routing without balancing. In both cases live traffic information was used. The results show improved average travel times for the distribution of travel demand across multiple paths during demand spikes.

Introduction
Floating car data (FCD) provides access to intrinsic properties of the traffic system such as the vehicle velocity. Compared to road-side infrastructure FCD provides a high spatial resolution and coverage on the level of individual road segments. It can be recorded by commodity mobile phones at a temporal resolution of 1 sample per second. This sampling rate enables the calculation of speed and acceleration profiles which can be used to evaluate fuel consumption and emissions per vehicle. [1]

Automotive travel in urban areas is dominated by congestion at bottlenecks as for instance traffic signals. Intelligent infrastructure adapts the timing of traffic signals to the travel demand to improve traffic flow. On the other hand, the existing capacity of the infrastructure can be used more efficiently by distributing the travel demand on the road network. Especially in high demand scenarios the prevention of congestion leads to significant travel time gains. Simulations demonstrated a travel time reduction as the travel demand was shifted by a dynamic toll [2].

Load balanced routing
The load balanced routing service which is used in the following is described in more detail in [3] and is only summarised here. The road network is represented as a mathematical graph for the path finding algorithm. Each road segment is assigned a cost which can be for example the average travel time. The cost is updated in real time with live traffic data. After calculating and returning a route the routing service stores a timed reservation for each road segment. When calculating a route, the impact of the additional vehicles on the travel time is predicted from the number of reservations by utilising the fundamental relations of traffic flow. As the mathematical graph stores information on the participants, it allows them to communicate with each other during route calculation like an intelligent swarm. Due to the capacity-dependent increase in travel time the travel demand is distributed across alternative paths with similar travel time.

Test drive setup

In the city of Hanover, Germany an artificial demand spike was created by sending 50 vehicles from the same origin to a common destination during the evening rush hour. The trajectories and speed profiles of the floating cars were recorded to measure the real-word effect of route choice on floating cars in a high demand scenario. The vehicles were split in two groups with 27 and 23 vehicles respectively. In each group the drivers were following the route guidance by a mobile navigation app. The first group was using *Google Maps* which has a good live traffic coverage in Hanover (individualistic routing) while the second group was following the route advice of *NUNAV Navigation* with live traffic data *and* load balanced routing. The two groups started interleaved on a supermarket parking lot. Origin and destination have been chosen such that the vehicles must cross the city centre and without a motorway nearby which usually would be the preferable choice.

Data acquisition

Several hardware solutions exist for vehicle tracking via GPS receivers. Aftermarket modules for the on-board diagnostics (OBD) port can be easily installed and are commonly used for fleet management. However, the typical position update interval is 10 s and the device stops transmitting when the vehicle is waiting at a traffic light. On the other hand, commodity mobile phones are equipped with GPS hardware and provide position updates on 1 s intervals. The higher temporal resolution improves the stop detection at traffic lights and allows to calculate acceleration profiles from the GPS trajectories. The data presented in this work was recorded by mobile phones and transmitted via the cell network to a central server.

Results

The key performance indicators are summarised in table 1. The values are given per vehicle as the mean over all vehicles. For each GPS trajectory the travel time between start and finish location was derived from the GPS timestamps. The travel distance was measured after matching the GPS trajectories to the road geometry from Open Street Map [citation]. The average speed is calculated from travel time and distance. The periods with a speed below 10 km/h are detected as stops and the durations of all stops are summarised. Additionally, the fuel consumption for a typical gasoline car has been simulated for the GPS trajectories using the *multi-model open-source vehicular-traffic simulator* (MovSim) [1].

Table 1: Mean performance indicators per vehicle

Route choice	Vehicles	Travel time	Distance	Speed	Stops	Fuel
Individualistic	27	0:31:22	13.5 km	26.0 km/h	0:13:25	1.175 l
Load balanced	23	0:28:17	12.2 km	26.2 km/h	0:09:47	1.091 l

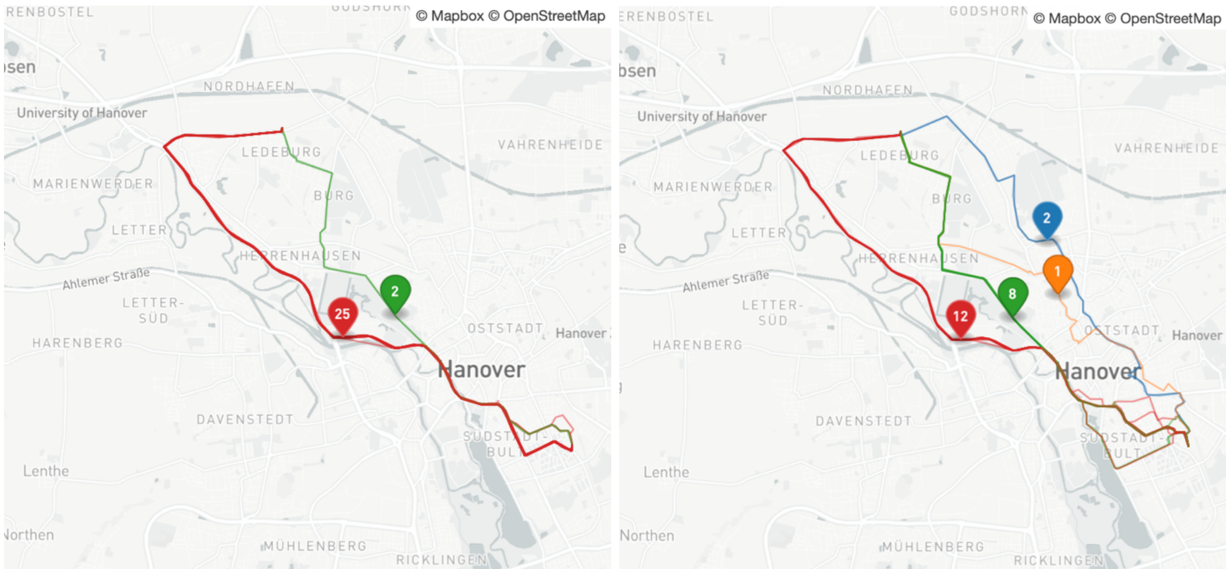

Figure 1: Route choice, left: individualistic routing, right: load balanced routing
The labels indicate the number of vehicles on the marked path. The origin is in the southeast and the destination is in the northwest.

The stop duration contributes significantly to the travel time. As shown in figure 1 the vehicles following load balanced routing are spreading out over the road network and different intersections. The lower travel time compared to the individualistic route choice can be contributed to shorter stops at traffic lights. The map shows a variety of paths and the different choices for the middle part are compared in table 2. The second half of the red path uses a dual carriage way. Thus, it has the highest average speed and fuel consumption. Additionally, the stop duration correlates with the volume of consumed fuel as the modelled gasoline car keep the engine running when waiting. There is not a single best path. However, according to the aggregated KPIs in table 1 it is beneficial to distribute the demand across multiple paths.

Table 2: Mean performance indicators per vehicle for each path

Route choice	Path	Vehicles	Travel time	Distance	Speed	Stops	Fuel
Individualistic	Red	25	0:31:37	13.8 km	26.4 km/h	0:13:42	1.193 l
Individualistic	Green	2	0:28:14	10.1 km	21.4 km/h	0:09:58	0.943 l
Load balanced	Red	12	0:27:23	13.7 km	30.1 km/h	0:09:29	1.177 l
Load balanced	Green	8	0:28:12	10.5 km	22.3 km/h	0:09:00	0.971 l
Load balanced	Orange	1	0:29:34	11.1 km	22.5 km/h	0:09:41	1.037 l
Load balanced	Blue	2	0:33:21	11.2 km	20.2 km/h	0:14:47	1.085 l

A closer look on the start

In table 2 the red path has different stop durations compared between the routing strategies even though the vehicles were driving at the same time. This is caused by different route choices in the first half of the journey. In the following only the vehicles on the red and green path in figure 1 are compared. Figure 2 shows the different paths taken by these vehicles in the beginning. The key performance indicators given in table 3 show that the stop duration can be decreased by distributing the travel demand on multiple paths.

Table 3: Mean performance indicators per vehicle for the first part

Route choice	Vehicles	Travel time	Distance	Speed	Stops	Fuel
Individualistic	27	14:08	3.5 km	15.4 km/h	7:40	0.401 l
Load balanced	20	11:18	3.5 km	18.7 km/h	4:25	0.380 l

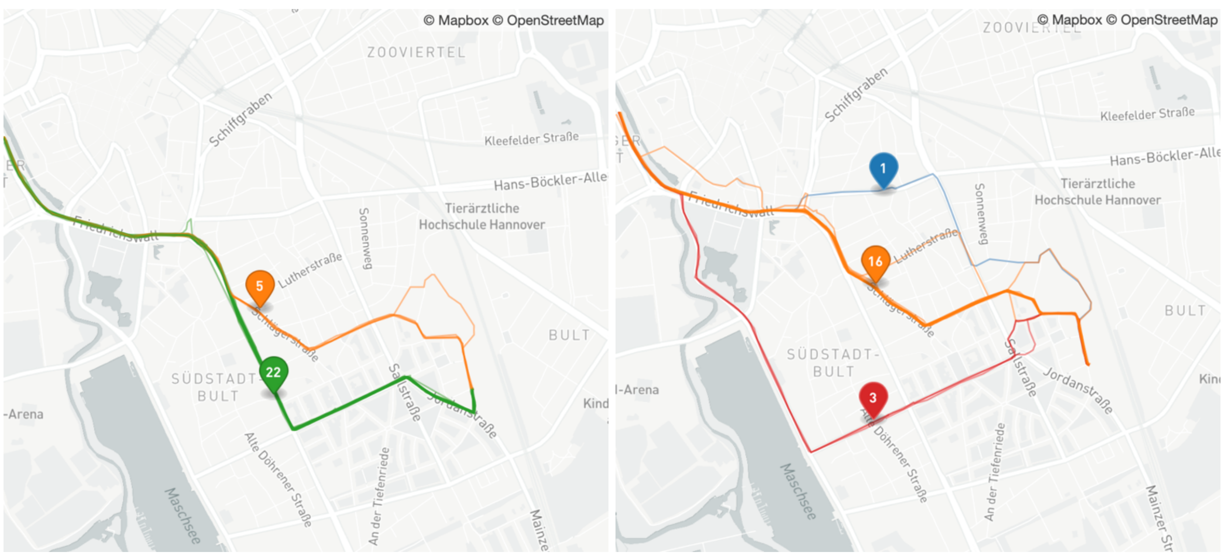

Figure 2: Route choice, left: individualistic routing, right: load balanced routing
The labels indicate the number of vehicles on the marked path.

Conclusion

The route choice has a significant influence on traffic flow. Even a good live traffic data coverage can not prevent congestion as the routing engine can only react after vehicles are slowing down. Individualistic routing is not using the road network efficiently because additional vehicles are assigned to a road segment until it becomes congested. Some cities aim to improve efficiency with a demand-based city toll to shift the travel demand towards the system optimum. The presented results show that a similar effect can be achieved by load balanced routing which includes the dynamic cost in the path finding algorithm without the need for a real-world toll.

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